Middle School Phenomenon Model Course 1 - Bundle 5
Fields of Force

This is the fifth bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the Course Flowchart.

Bundle 1 Question: This bundle is assembled to address the questions of "*How can objects interact at a distance?*"

Summary

The bundle organizes performance expectations with a focus on helping students understand the interaction of objects when they are not in physical contact with one another. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

The concept that, when two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object (PS3.C as in MS-PS3-2) can connect to the idea that forces that act at a distance (electric and magnetic) can be explained by fields that extend through space (PS2.B as in MS-PS2-5). These ideas also connect to the concept that electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects (PS2.B as in MS-PS2-3).

Additionally, these ideas about forces that act at a distance can be connected to the concept that gravitational forces are always attractive; there is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun (PS2.B as in MS-PS2-4). Then, gravitational forces connect to the concepts that the solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them (ESS1.B as in MS-ESS1-3 and MS-ESS1-2) and this model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year **(**ESS1.B as in MS-ESS1-1).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of asking questions and defining problems (MS-PS2-3), developing and using models (MS-PS3-2, MS-ESS1-1, and MS-ESS1-2), planning and carrying out investigations (MS-PS2-5), analyzing and interpreting data (MS-ESS1-3), and engaging in argument from evidence (MS-PS2-4). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-ESS1-1), Cause and Effect (MS-PS2-3 and MS-PS2-5), Systems and System Models (MS-PS2-4, MS-PS3-2, and MS-ESS1-2), and Scale, Proportion, and Quantity (MS-ESS1-3). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-PS2-3. **Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.** [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*] MS-PS2-4. **Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*] MS-PS2-5. **Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.** [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*] MS-PS3-2. **Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.** [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*] MS-ESS1-1. **Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.** [Clarification Statement: Examples of models can be physical, graphical, or conceptual.] MS-ESS1-2. **Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.** [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*] MS-ESS1-3. **Analyze and interpret data to determine scale properties of objects in the solar system.** [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

Example Phenomena	Static electricity can make small objects like thread and grains of salt come up off the table. An electric motor uses electrical energy and produces motion. The pattern of the phases of the moon repeats over and over again. If you rub a balloon on your hair, your hair will stand up.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** ● Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. Students could *ask questions that arise from careful observation of phenomena or models* [related to the] **apparent motion of the sun, the moon, and stars in the sky** *to clarify and/or seek additional information*. MS-ESS1-1 **Developing and Using Models** ● Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed. Students could *modify a model* [of] **fields that extend through space and their effect on an object**, *based on evidence, to match what happens if a variable or component of a system is changed*. MS-PS2-5 **Planning and Carrying Out Investigations** ● Collect data to produce data to serve as the basis for evidence to answer scientific questions Students could *collect data to serve as the basis for evidence to answer scientific questions* [about what effects] **the size of electric and magnetic forces**. MS-PS2-3 **Analyzing and Interpreting Data** ● Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. Students could *analyze data to define an optimal operational range for a proposed tool* [that incorporates] **electric forces,** [whose] **sizes depend on the magnitudes of the charges and currents involved and on the distances between the interacting objects**. MS-PS2-3 **Using Mathematics and Computational Thinking** ● Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem. Students could *use digital tools to test and compare proposed solutions* [that incorporate] **magnetic forces,** [which] **can be attractive or repulsive**. MS-PS2-3

Additional Practices Building to the PEs (Continued)	**Constructing Explanations and Designing Solutions** ● Construct an explanation using models or representations. Students could *construct an explanation using models or representations* [related to the concept that] **the solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them**. MS-ESS1-3 and MS-ESS1-3 **Engaging in Argument from Evidence** ● Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. Students could *evaluate competing design solutions* [that use] **stored (potential) energy –** [which] **depends on the relative positions** [of objects]. MS-PS3-2 **Obtaining, Evaluating, and Communicating Information** ● Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims or findings. Students could *integrate qualitative and/or quantitative scientific information in written text* [about the] **gravitational force between any two masses,** [which] **is very small except when one or both of the objects have large mass,** *with that contained in media and visual displays to clarify claims or findings*. MS-PS2-4
Additional Crosscutting Concepts Leading to the PEs	**Cause and Effect** ● Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could use *cause and effect relationships to predict phenomena in natural or designed systems* [related to the concept that] **a system of objects may contain stored (potential) energy, depending on their relative positions**.MS-PS3-2 **Systems and System Models** ● Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Students could *use a model to represent systems* [of] **forces that act at a distance (electric and magnetic)** *and their interactions and energy flows* [by] mapping their effect on an object (e.g., a charged object, or a ball). MS-PS2-5 **Scale, Proportion, and Quantity** ● Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. Students could describe that *space phenomena*—such as **eclipses of the sun and the moon,** [as well as] **the seasons,** [which] **are a result of** [Earth's tilt] **relative to its orbit around the sun and are caused by the differential intensity of sunlight on different areas of Earth across the year—***can be observed at various scales using models to study systems that are too large* [to observe directly]. MS-ESS1-1

Additional Connections to Nature of Science	**Science is a Way of Knowing** ● Science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge. Students could describe how *science knowledge is cumulative and many people, from many generations and nations, have contributed to science knowledge* [about how] **Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe**. MS-ESS1-2 **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** ● Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. *Science assumes that objects and events in natural systems* [such as] **the motion of the sun, the moon, and stars in the sky** *occur in consistent patterns that are understandable through measurement and observation*. MS-ESS1-1

MS-PS2-3 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds from grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**PS2.B: Types of Interactions** • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:				
1	Addressing phenomena of the natural world or scientific theories			
	a	Students formulate questions that arise from examining given data of objects (which can include particles) interacting through electric and magnetic forces, the answers to which would clarify:		
		i.	The cause-and-effect relationships that affect magnetic forces due to:	
			1.	The magnitude of any electric current present in the interaction, or other factors related to the effect of the electric current (e.g., number of turns of wire in a coil).
			2.	The distance between the interacting objects.
			3.	The relative orientation of the interacting objects.
			4.	The magnitude of the magnetic strength of the interacting objects.
		ii.	The cause-and-effect relationship that affect electric forces due to:	
			1.	The magnitude and signs of the electric charges on the interacting objects.
			2.	The distances between the interacting objects.
			3.	Magnetic forces.
	b	Based on scientific principles and given data, students frame hypotheses that:		
		i.	Can be used to predict the strength of electric and magnetic forces due to cause-and-effect relationships.	
		ii.	Can be used to distinguish between possible outcomes, based on an understanding of the cause-and-effect relationships driving the system.	
2	Identifying the scientific nature of the question			
	a	Students' questions can be investigated scientifically within the scope of a classroom, outdoor environment, museum, or other public facility.		

MS-PS2-4 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds from K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.

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Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Observable features of the student performance by the end of the course:

1	Supported claims		
	a	Students make a claim to be supported about a given phenomenon. In their claim, students include the following idea: Gravitational interactions are attractive and depend on the masses of interacting objects.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including:	
		i.	The masses of objects in the relevant system(s).
		ii.	The relative magnitude and direction of the forces between objects in the relevant system(s).
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence, and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the appropriate evidence about the forces on objects and construct the argument that gravitational forces are attractive and mass dependent. Students describe* the following chain of reasoning:	
		i.	Systems of objects can be modeled as a set of masses interacting via gravitational forces.
		ii.	In systems of objects, larger masses experience and exert proportionally larger gravitational forces.

		iii. In every case for which evidence exists, gravitational force is attractive.
	b	To support the claim, students present their oral or written argument concerning the direction of gravitational forces and the role of the mass of the interacting objects.

MS-PS2-5 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [*Assessment Boundary: Assessment is limited to electric and magnetic fields, and limited to qualitative evidence for the existence of fields.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Disciplinary Core Ideas

PS2.B: Types of Interactions

- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon to be investigated		
	a	From the given investigation plan, students identify the phenomenon under investigation, which includes the idea that objects can interact at a distance.	
	b	Students identify the purpose of the investigation, which includes providing evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.	
2	Identifying evidence to address the purpose of the investigation		
	a	From the given plan, students identify and describe* the data that will be collected to provide evidence for each of the following:	
		i.	Evidence that two interacting objects can exert forces on each other even though the two interacting objects are not in contact with each other.
		ii.	Evidence that distinguishes between electric and magnetic forces.
		iii.	Evidence that the cause of a force on one object is the interaction with the second object (e.g., evidence for the presence of force disappears when the second object is removed from the vicinity of the first).
3	Planning the investigation		
	a	Students describe* the rationale for why the given investigation plan includes:	
		i.	Changing the distance between objects.
		ii.	Changing the charge or magnetic orientation of objects.
		iii.	Changing the magnitude of the charge on an object or the strength of the magnetic field.
		iv.	A means to indicate or measure the presence of electric or magnetic forces.
4	Collecting the data		
	a	Students make and record observations according to the given plan. The data recorded may include observations of:	
		i.	Motion of objects.
		ii.	Suspension of objects.
		iii.	Simulations of objects that produce either electric or magnetic fields through space and the effects of moving those objects closer to or farther away from each other.
		iv.	A push or pull exerted on the hand of an observer holding an object.

5	Evaluation of the design	
	a	Students evaluate the experimental design by assessing whether or not the data produced by the investigation can provide evidence that fields exist between objects that act on each other even though the objects are not in contact.

MS-PS3-2 Energy

Students who demonstrate understanding can:

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationship Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems and System Models** • Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

Observable features of the student performance by the end of the course:

1	Components of the model		
	a	To make sense of a given phenomenon involving two objects interacting at a distance, students develop a model in which they identify the relevant components, including:	
		i.	A system of two stationary objects that interact.
		ii.	Forces (electric, magnetic, or gravitational) through which the two objects interact.
		iii.	Distance between the two objects.
		iv.	Potential energy.
2	Relationships		
	a	In the model, students identify and describe* relationships between components, including:	
		i.	When two objects interact at a distance, each one exerts a force on the other that can cause energy to be transferred to or from an object.
		ii.	As the relative position of two objects (neutral, charged, magnetic) changes, the potential energy of the system (associated with interactions via electric, magnetic, and gravitational forces) changes (e.g., when a ball is raised, energy is stored in the gravitational interaction between the Earth and the ball).
3	Connections		
	a	Students use the model to provide a causal account for the idea that the amount of potential energy in a system of objects changes when the distance between stationary objects interacting in the system changes because:	
		i.	A force has to be applied to move two attracting objects farther apart, transferring energy to the system.
		ii.	A force has to be applied to move two repelling objects closer together, transferring energy to the system.

MS-ESS1-1 Earth's Place in the Universe

Students who demonstrate understanding can:

MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.B: Earth and the Solar System

- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

Crosscutting Concepts

Patterns

- Patterns can be used to identify cause-and-effect relationships.

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon involving, students develop a model (e.g., physical, conceptual, graphical) of the Earth-moon-sun system in which they identify the relevant components, including:	
		i.	Earth, including the tilt of its axis of rotation.
		ii.	Sun.
		iii.	Moon.
		iv.	Solar energy.
	b	Students indicate the accuracy of size and distance (scale) relationships within the model, including any scale limitations within the model.	
2	Relationships		
	a	In their model, students describe* the relationships between components, including:	
		i.	Earth rotates on its tilted axis once an Earth day.
		ii.	The moon rotates on its axis approximately once a month.
		iii.	Relationships between Earth and the moon:
			1. The moon orbits Earth approximately once a month.
			2. The moon rotates on its axis at the same rate at which it orbits Earth so that the side of the moon that faces Earth remains the same as it orbits.
			3. The moon's orbital plane is tilted with respect to the plane of the Earth's orbit around the sun.
		iv.	Relationships between the Earth-moon system and the sun:
			1. Earth-moon system orbits the sun once an Earth year.

		2. Solar energy travels in a straight line from the sun to Earth and the moon so that the side of Earth or the moon that faces the sun is illuminated.
		3. Solar energy reflects off of the side of the moon that faces the sun and can travel to Earth.
		4. The distance between Earth and the sun stays relatively constant throughout the Earth's orbit.
		5. Solar energy travels in a straight line from the sun and hits different parts of the curved Earth at different angles — more directly at the equator and less directly at the poles.
		6. The Earth's rotation axis is tilted with respect to its orbital plane around the sun. Earth maintains the same relative orientation in space, with its North Pole pointed toward the North Star throughout its orbit.
3	Connections	
	a	Students use patterns observed from their model to provide causal accounts for events, including:
		i. Moon phases:
		1. Solar energy coming from the sun bounces off of the moon and is viewed on Earth as the bright part of the moon.
		2. The visible proportion of the illuminated part of the moon (as viewed from Earth) changes over the course of a month as the location of the moon relative to Earth and the sun changes.
		3. The moon appears to become more fully illuminated until "full" and then less fully illuminated until dark, or "new," in a pattern of change that corresponds to what proportion of the illuminated part of the moon is visible from Earth.
		ii. Eclipses:
		1. Solar energy is prevented from reaching the Earth during a solar eclipse because the moon is located between the sun and Earth.
		2. Solar energy is prevented from reaching the moon (and thus reflecting off of the moon to Earth) during a lunar eclipse because Earth is located between the sun and moon.
		3. Because the moon's orbital plane is tilted with respect to the plane of the Earth's orbit around the sun, for a majority of time during an Earth month, the moon is not in a position to block solar energy from reaching Earth, and Earth is not in a position to block solar energy from reaching the moon.
		iii. Seasons:
		1. Because the Earth's axis is tilted, the most direct and intense solar energy occurs over the summer months, and the least direct and intense solar energy occurs over the winter months.
		2. The change in season at a given place on Earth is directly related to the orientation of the tilted Earth and the position of Earth in its orbit around the sun because of the change in the directness and intensity of the solar energy at that place over the course of the year.
		a. Summer occurs in the Northern Hemisphere at times in the Earth's orbit when the northern axis of Earth is tilted toward the sun. Summer occurs in the Southern Hemisphere at times in the Earth's orbit when the southern axis of Earth is tilted toward the sun.
		b. Winter occurs in the Northern Hemisphere at times in the Earth's orbit when the northern axis of Earth is tilted away from the sun. Summer occurs in the Southern Hemisphere at times in the Earth's orbit when the southern axis of Earth is tilted away from the sun.
	b	Students use their model to predict:
		i. The phase of the moon when given the relative locations of the Earth, sun, and moon.
		ii. The relative positions of the Earth, sun, and moon when given a moon phase.
		iii. Whether an eclipse will occur, given the relative locations of the Earth, sun, and moon and a position on Earth from which the moon or sun can be viewed (depending on the type of eclipse).
		iv. The relative positions of the Earth, sun, and moon, given a type of eclipse and a position on Earth from which the moon/sun can be viewed.

		v.	The season on Earth, given the relative positions of Earth and the sun (including the orientation of the Earth's axis) and a position on Earth.
		vi.	The relative positions of Earth and the sun when given a season and a relative position (e.g. far north, far south, equatorial) on Earth.

MS-ESS1-2 Earth's Place in the Universe

Students who demonstrate understanding can:

MS-ESS1-2. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models

Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars

- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B: Earth and the Solar System

- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions.

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Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

- Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	To make sense of a given phenomenon, students develop a model in which they identify the relevant components of the system, including:	
		i.	Gravity.
		ii.	The solar system as a collection of bodies, including the sun, planets, moons, and asteroids.
		iii.	The Milky Way galaxy as a collection of stars (e.g., the sun) and their associated systems of objects.
		iv.	Other galaxies in the universe
	b	Students indicate the relative spatial scales of solar systems and galaxies in the model.	
2	Relationships		
	a	Students describe* the relationships and interactions between components of the solar and galaxy systems, including:	
		i.	Gravity as an attractive force between solar system and galaxy objects that:
			1. Increases with the mass of the interacting objects increases.
			2. Decreases as the distances between objects increases.
		ii.	The orbital motion of objects in our solar system (e.g., moons orbit around planets, all objects within the solar system orbit the sun).
		iii.	The orbital motion, in the form of a disk, of vast numbers of stars around the center of the Milky Way.
		iv.	That our solar system is one of many systems orbiting the center of the larger system of the Milky Way galaxy.

		v. The Milky Way is one of many galaxy systems in the universe.
3	Connections	
	a	Students use the model to describe* that gravity is a predominantly inward-pulling force that can keep smaller/less massive objects in orbit around larger/more massive objects.
	b	Students use the model to describe* that gravity causes a pattern of smaller/less massive objects orbiting around larger/more massive objects at all system scales in the universe, including that:
		i. Gravitational forces from planets cause smaller objects (e.g., moons) to orbit around planets.
		ii. The gravitational force of the sun causes the planets and other bodies to orbit around it, holding the solar system together.
		iii. The gravitational forces from the center of the Milky Way cause stars and stellar systems to orbit around the center of the galaxy.
		iv. The hierarchy pattern of orbiting systems in the solar system was established early in its history as the disk of dust and gas was driven by gravitational forces to form moon-planet and planet-sun orbiting systems.
	c	Students use the model to describe* that objects too far away from the sun do not orbit it because the sun's gravitational force on those objects is too weak to pull them into orbit.
	d	Students use the model to describe* what a given phenomenon might look like without gravity (e.g., smaller planets would move in straight paths through space, rather than orbiting a more massive body).

MS-ESS1-3 Earth's Place in the Universe

Students who demonstrate understanding can:

MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system. [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object's layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings.	**ESS1.B: Earth and the Solar System** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.	**Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. - ***Connections to Engineering, Technology, and Applications of Science*** **Interdependence of Science, Engineering, and Technology** • Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems.

Observable features of the student performance by the end of the course:		
1	Organizing data	
	a	Students organize given data on solar system objects (e.g., surface features, object layers, orbital radii) from various Earth- and space-based instruments to allow for analysis and interpretation (e.g., transforming tabular data into pictures, diagrams, graphs, or physical models that illustrate changes in scale).
	b	Students describe* that different representations illustrate different characteristics of objects in the solar system, including differences in scale.
2	Identifying relationships	
	a	Students use quantitative analyses to describe* similarities and differences among solar system objects by describing* patterns of features of those objects at different scales, including:
		i. Distance from the sun.
		ii. Diameter.
		iii. Surface features (e.g., sizes of volcanoes).
		iv. Structure.
		v. Composition (e.g., ice versus rock versus gas).

	b	Students identify advances in solar system science made possible by improved engineering (e.g., knowledge of the evolution of the solar system from lunar exploration and space probes) and new developments in engineering made possible by advances in science (e.g., space-based telescopes from advances in optics and aerospace engineering).
3	Interpreting data	
	a	Students use the patterns they find in multiple types of data at varying scales to draw conclusions about the identifying characteristics of different categories of solar system objects (e.g., planets, meteors, asteroids, comets) based on their features, composition, and locations within the solar system (e.g., most asteroids are rocky bodies between Mars and Jupiter, while most comets reside in orbits farther from the sun and are composed mostly of ice).
	b	Students use patterns in data as evidence to describe* that two objects may be similar when viewed at one scale (e.g., types of surface features) but may appear to be quite different when viewed at a different scale (e.g., diameter or number of natural satellites).
	c	Students use the organization of data to facilitate drawing conclusions about the patterns of scale properties at more than one scale, such as those that are too large or too small to directly observe.